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Harnessing 'water tower' into 'power tower': A small hydropower development study from an Indian prefecture in western Himalayas

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ABSTRACT

Himalayan region is called the 'water tower of Asia'. This 'water tower' is now being harnessed into 'power tower' by many Himalayan countries (China, India, Nepal, Bhutan etc.) in the form of small and large hydropower projects. Himachal Pradesh, located in this region is known as 'power state' of India. The state has developed well framed policies and guidelines for growth of hydropower sector in the state. It has emerged as role model for identification, allotment and harnessing of small hydropower projects not only in India but in the whole Himalayan region. However, in the recent past, the growth of small hydropower projects is not as impressive as predicted. Local natural resources, ecology and livelihood of the local people are being destroyed in the garb of local development and false promises of employment. Benefits of this so called golden harvest are not being transferred to native people as envisaged. This article presents small hydropower development in a global, Indian and Himachal Pradesh perspective. It expresses in detail the current status, policy guidelines, challenges, initiatives taken by state, future scope and suggestions for smooth development of small hydropower projects in this beautiful, hydro rich hilly state of India. It is concluded that framing of policies favoring sustainable development and their effective implementation at grass-root level (involving all stakeholders) can only set the ball rolling for desired pace of small hydropower development in the state. Bringing of small hydropower projects in the ambit of environmental clearance process has also been advocated.

Contents

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1. Introduction

With glacier coverage of about 33,000 km^2, Himalayan region has the largest concentration of glaciers outside the polar caps. The glacier-fed rivers originating from the Himalaya mountain ranges surrounding the Tibetan Plateau comprise the largest river run-off from any single location in the world. These Himalayan glaciers feed seven of Asia's great rivers: the Ganga, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang Ho and ensure a year round water supply to about one billion people [1]. Perennial rivers and their tributaries in this region present a golden opportunity to harness water power in the form of small and large hydropower projects.

India occupies 6th position in the world both in terms of installed hydropower capacity and energy consumption [2,3]. It is one of the fastest growing economies of the world and has also set an ambitious target to become a developed nation by 2020. This country is also set to become the most populated nation of the world by 2050. To keep pace of growing economy, to achieve target of becoming a developed nation in near future and to fulfill demand of ever burgeoning population, energy is the prime mover. In India, still about 70% of energy is produced by fossil fuel based power projects [4].

Diminishing reserves, mounting prices of fossil energy sources and their impact on the environment has made hydropower a more important and attractive energy source [5]. Hence, great emphasis is being laid on fast development of hydropower projects in this region by tapping indigenous water resources. A lion's share of hydropower potential in India comes from the Himalayan states. However, large hydropower projects (especially reservoir based) are now facing the protests by local communities as well as environmentalists on social and environmental fronts [6–8]. In this scenario, small hydropower projects (SHPs) have become 'blue eyed boys' of energy planners.

2. Small hydropower development

Small hydropower is worldwide recognized as a 'genuine' renewable energy resource. Owing to the proved environmental impacts, large hydropower projects are no more considered 'renewable' by many researches and organizations [9–11].

2.1. Benefits of SHPs

SHPs have certain intrinsic advantages. They generate clean energy at a competitive cost. The technology used in these projects is quite mature and largely indigenous. Moreover, they are less affected by rehabilitation and resettlement (R&R) problems as compared to large hydropower plants. They can meet the power requirements of remote and isolated areas. It has the least adverse environmental impact (i.e. greenhouse gas, SO_2, NO_x emission) and has the most energy payback ratio when compared among all electricity generation systems [12]. One GW h of electricity produced by small hydropower means a reduction of CO_2 emissions by 480 t [13].

SHPs typically have an inherent ability for instantaneous starting, stopping and load variations. Their maximum power production is in the summer (due to melting of glaciers) and monsoon seasons. More power production augments the power supply in plain regions of India in these seasons when demand of electricity is at peak. Hence, a significant part of the generation season of SHPs coincides with peak seasonal demand in India [14].

2.2. Global perspective

Hydropower projects are having an overall installed capacity of 990 GW worldwide as on 2012 [15]. Out of this stated capacity, small hydro ($<$ 10 MW) currently contributes over 40 GW of world capacity. There is no universal consensus on definition of small hydro. Threshold limit varies from 5 MW in one country to 50 MW in other country [16,17]. The global small hydro potential is believed to be in excess of 100 GW. China is world leader in term of both large and small hydropower capacity. This country alone has developed more than 15 GW of small hydropower and plans to develop a further 10 GW in the current decade [18]. Many researchers across the globe had undertaken studies on small hydropower development in their respective regions. Some of these studies have been reviewed in Table 1.

Extensive global literature review in terms of small hydropower development indicates that SHPs are important renewable energy source across the globe. Small hydropower is likely to expand especially in developing as well as in economically aspiring and populous countries to cater to energy demand in rural areas.

2.3. Indian perspective

SHPs occupy an important place among available renewable energy sources in India. These installations comprise the second largest share (after wind energy) of the total renewable energy installed in the country [14,33].

2.3.1. History and current status

In India, the first ever SHP for generating electricity was commissioned in 1897, at Darjeeling (West Bengal). It had a capacity of 130 kW. This project was followed by Sivasamudram project of 4.5 MW in Mysore district of Karnataka in 1902, which supplied power to Kolar gold mines [34]. At the time of independence of India i.e. in 1947, installed capacity of hydropower was mere 508 MW [35].

After independence, more emphasis was given on development of reservoir based large hydro projects in India. These projects were called 'temples of modern India'. But by the end of 20th century, trend started changing in favor of run of the river (ROR) type hydropower projects (especially SHPs). This change in trend was mainly due to increased fossil fuel prices, environmental concerns (due to thermal power projects) and above all public outrage against reservoir based large hydro projects due to large scale submergence and displacement problems caused by these projects.

Presently, 6474 sites with a potential of about 19,749.44 MW have been identified in India by Ministry of New and Renewable Energy (MNRE) for establishment of SHPs. As on 31.01.2014, India's total installed capacity for SHPs was about 3774.15 MW [36]. This

Table 1
Global perspective of small hydropower development from different parts of world.

Author(s)	Study region	Major findings/conclusion with respect to small hydropower development in the region under study
Xingang et al. [19], Chang et al. [20]	China	• SHPs can bring direct benefits for local government and people in the form of rural employment, less use of woody fuel, reducing environmental pollution, cheap electricity • China must accelerate the SHPs according to local conditions and take benefit of CDM (Clean Development Mechanism) incentives in order to realize the sustainable development of economy, environment and society. Building of healthy investment and operation environment is also crucial • SHPs have advantages of no emigration, appropriate scale, mature technology, low investment, short construction period, advance technology etc.
Osmani et al. [21], Kosnik [22]	USA	• Future hydropower projects in US will be limited to small-scale, low-head power, "run-of-the-river" projects or upgrades (and expansions) to existing large-scale hydropower projects as most of the best sited have been already developed/tapped under large hydropower projects • Streamlining of regulatory process especially catering to SHPs will go a long way towards improving the incentives for small hydropower development • Site accessibility, transmission and load proximity, and land use sensitivities are main three factors affecting the feasibility of SHPs
Bahadori et al. [23]	Australia	• SHPs are still at a relatively early stage of development in Australia, and are expected to be the main source of future growth in hydro electricity generation as most of Australia's most favorable hydroelectricity sites have been already developed • SHPs are potentially viable on smaller rivers and streams where large dams are not technically feasible or environmentally acceptable • SHPs have low water requirement, lower environmental footprint and less development cost
Spänhoff [15]	Germany	• In most of industrially developed nations including Germany, most locations for hydro that are both economical to develop and also meet environmental regulations already have been already exploited. However, Germany is leading in the number of SHPs among the member states of the EU • Stringent norms given by WFD (Water Framework Directive) for protection, enhancement and restoration of streams and rivers are not conducive for development of hydropower plants (even SHPs) in most of EU nations including Germany
Kaldellis [24], Malesios and Arabatzis [25]	Greece	• SHP installations are a financial attractive and an environmental friendly solution, able to contribute remarkably to the solution of the energy demand problem of Greece • Despite the interest of private investors, growth of SHPs is Greece is not up to expectation mainly due to decision making problems, like the administrative bureaucracy, absence of a rational water resources management plan and over-sizing of existing/proposed installation • Employment opportunities, socio-economic factors, reasonable rate of small hydropower, publicizing the environmental friendliness are important factors to get wider support of local communities for SHPs
Panić et al. [26]	Serbia	• The greatest disadvantages of SHPs are related with great costs accompanying the exploration of potential sites for their construction (costs of preliminary and main project drafting), complicated permit-issuing procedures and the great initial investments • Some of the possible solutions to boost SHPs would include drafting of the new Survey of SHPs; a long-term energy strategy; strict application of ecological measures when planning and devising projects in compliance with EU directives; defining criteria and rules for the utilization of water courses for SHPs and strict control of development activities and resource exploitation
Kaunda et al. [16], Kaunda [27]	Sub-Saharan Africa, Malawi	• Small hydropower technology is one of the promising decentralized power generation systems for rural electricity supply in the region. However, its level of installation is very low • Main challenges hampering development and implementation of SHP projects in the region are technological challenges including lack of local human capacity to plan, design, manufacture, install and operate SHPs. In case of rural electrification, involvement of local authority and local communities is crucial • There is need for a design of modularized and standardized SHP system to be applied to a range of potential sites. Spreading awareness of SHP technology, development of feed-in-tariff system and standard power purchase agreement are important factors to attract private investors • SHPs are quite energy efficient and important clean energy system considered for carbon trading
Taele et al. [5]	Lesotho (a S. African country)	• For a poor country such as Lesotho, SHPs can meet financial and technical demands by small investors with relative ease. • Key advantages of SHPs are high efficiency (70–90%), high capacity factor, long lasting and robust technology. They are suitable for areas considered unviable for grid extension, attractive to be located in stand-alone or hybrid combination.
Dursun and Gokcol [12], Kucukali [28]	Turkey	• SHPs generally don't require storage or back-up systems, lead to an improved rural economy, provide cheaper electricity for domestic use and are having minimal or ignorable environmental problems as compared to large counterparts. Site geology and environmental issues are the key risk factors for the success of a SHP project • Turkish government has taken various measures to attract investors in this largely up-tapped sector (like assured buying of electricity, large discount for forest and land acquisition to build SHPs etc.) • Despite their doubtless advantages, SHP projects can lead to several environmental risks such as: lower water quality, ecosystem destruction and biodiversity loss, inadequate environmental flow. With the adoption of WFD, non-sustainable development of SHPs will not be possible

Table 1 (*continued*)

Author(s)	Study region	Major findings/conclusion with respect to small hydropower development in the region under study
Martins et al. [29]	Brazil	• CDM may foster investment in SHPs, increasing their financial attractiveness, and drawing the attention of energy sector investors • In the Brazilian context of SHP project implementation, the CDM might still be considered a time consuming, complex, and bureaucratic mechanism, requiring patience, objectivity and persistence from the project proponents • The uncertainty still surrounding the post 2012 period, which marks the end of the first commitment period set out in the Kyoto Protocol, is cause of further concern for prospective project proponents
Sharma et al. [30], Nautiyal et al. [31], Reddy et al. [32]	India	• There is growing interest for the development of substantial SHP potential in India as it is considered as most promising and economically viable form of renewable energy (in terms of generation cost, pay-back period, efficiency etc.) • Involvement of the local communities and direct livelihood benefits to them are essential for the long-term sustainability of the small hydro schemes. However, assessing the local impacts and attributing the benefits to the SHPs is especially a difficult task in case of already grid connected villages • Central and state governments in India are providing various incentives for development of SHPs

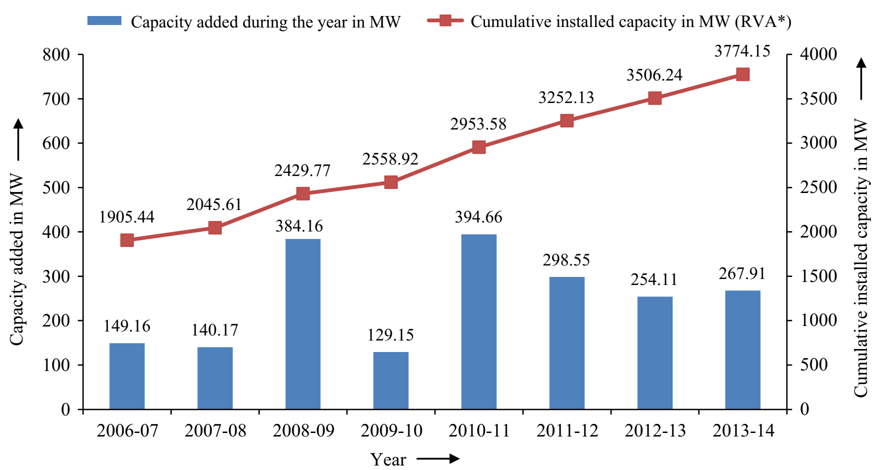

Fig. 1. Growth of installed capacity addition of SHPs in India in recent years [37].

Table 2
Classification of SHPs in India.
Source: [38].

Class	Station capacity in kW
Micro hydro	Up to 100
Mini hydro	101 to 2000
Small hydro	2001 to 25,000

is about 19% of the total potential of available in the country and about 13% of the country's total installed renewable energy capacity. Fig. 1 presents the growth of small hydropower development in India during the last few years.

Fig. 1 indicates that addition of SHP capacity during the last 3 years has not been so impressive and the growth has been more or less stagnant. In the year 2012–2013, India was able to add only 28.80% (100.83 MW) against the target of 350 MW. Progress during the year 2013–14 has also not been remarkable. In spite of reduced target (300 MW), capacity addition achieved was about 44% (130.90 MW) [33].

2.3.2. *Classification of SHPs*

Hydropower projects are largely classified into two types i.e. small and large hydro. In India, hydro projects up to 25 MW station capacities have been classified as SHPs. Ministry of Power;

Table 3
Criteria for selecting potential sites for SHP development.
Sources: [40–42].

S. no.	Criteria	Remarks
1.	Availability of perennial (glacier fed) stream	Generation for maximum part of the year and less generation cost
2.	Steep bed slope of the stream	Availability of more head in comparatively lesser diverted reach of the stream and less generation cost
3.	Available infrastructural and communication facilities	Less capital cost and gestation period
4.	Nearness to connection point with the grid	Less cost of transmission line
5.	Good geology to support tunnel construction and other major project components (weir, de-sanding tank, surge shaft, penstock, power house etc.)	Less probability of geological surprises, less development
6.	Less population	Comparatively more public acceptance and less expenditure on compensation
7.	Easy availability of land	Less expenditure on land procurement
8.	Availability of local construction materials like sand, coarse aggregates etc.	Less cost of transportation for construction materials
9.	Site not located inside/very near to forest or some wild-life century, other protected area(s)	Less difficulty in obtaining NOC/ statutory clearance(s)

Government of India is responsible for large hydro projects while SHPs are dealt by MNRE. In Himalayan states of India, almost 100% SHPs are ROR type. Classification of SHPs in India is given in Table 2.

2.3.3. Norms for environment impact assessment (EIA) with respect to SHPs

In India, SHPs (having installed capacity less than 25 MW) have been exempted from environmental clearance i.e. they need not to

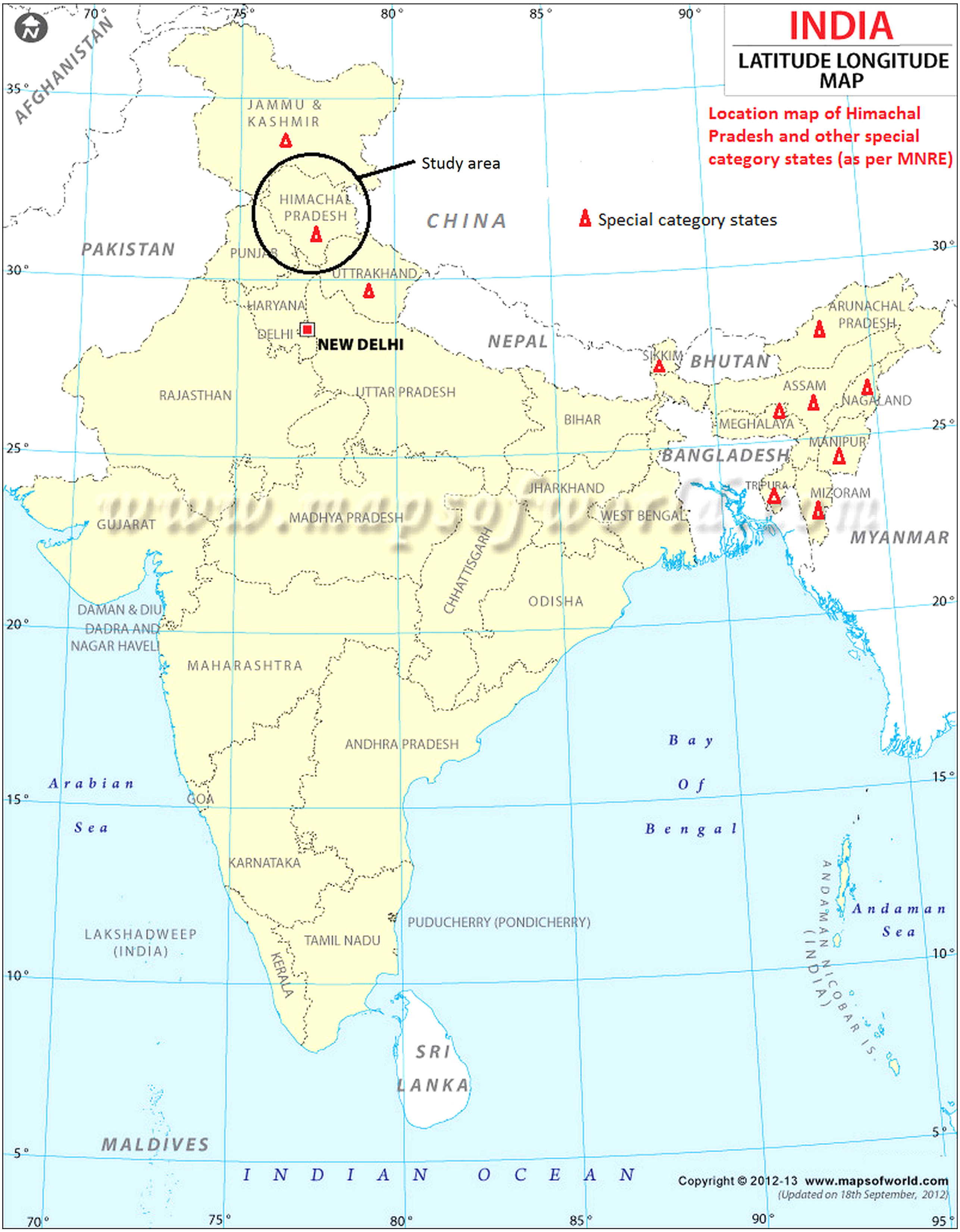

Fig. 2. Location map of Himachal Pradesh (India) [43].

undergo process of EIA [39]. However, there are conditions under which EIA and environmental clearance may become necessary. These conditions are:

a) If the project is located in side or within 10 km distance from boundary of
   i) Protected area under 'wild life (protection) act, 1972'.
   ii) Critically protected area.
   iii) Notified eco-sensitive area.
   iv) International boundary.
b) If expansion or modernization of existing unit results in increase in plant capacity beyond 25 MW threshold limit.
c) If the cumulative impacts of proposed project in conjunction with existing or proposed hydropower projects in vicinity are expected to be significant.
d) If the funding agency specifies EIA as a precondition for funding of the project. For example, an international funding agency may specify such condition.

2.3.4. Criteria for selecting potential sites for SHP development

Proper selection of site for small hydropower development is very important. This will avoid future time and cost over-runs. Hence, this step will lead to timely generation of profit for the developer and revenue for the government. Some of the criteria for selection of potential sites for SHP development have been highlighted in Table 3.

3. Study area: Himachal Pradesh

Himachal, meaning the land of snow, is one of the most beautiful Himalayan states of Indian union situated in its north. Location of the state of Himachal Pradesh in map of India has been shown in Fig. 2 (encircled). The state is having an area of 55673 km^2, population of about 7 million and it is located at a height varying from 350 to 6975 m above mean sea level (MSL). It is bound between latitude 32°22′40″ to 33°12′40″N and longitude 75°74′55″ to 79°04′20″E. A brief profile of Himachal Pradesh is given in Table 4.

This state consists of enchanting hills, deep and green valleys, popular pilgrim centers, unexplored regions bathed in pristine beauty, culturally unique and rich tribal areas, gurgling streams and alpine flora. Since the 1990s, Himachal Pradesh has grown faster than the national average and is ahead in terms of most indicators of human development. It is performing better than several more developed states on the plains in terms of social and economic progress. This state is generously gifted with water resources and topography, which is suitable for development of large and small hydropower projects. Five perennial rivers Satluj, Beas, Ravi, Chenab and Yamuna flow through its territory. These rivers possess immense potential for the generation of hydroelectricity. This study area is also special in the sense that the state has already achieved unique distinction of electrification of 100% revenue villages [45] and almost all villages of the state are grid connected.

Table 4
Brief profile of Himachal Pradesh (India).
Source: [44].

Particulars	Unit/measure	Quantity
Area	km^2	55673
Location	N. Latitude	32°22′40″ to 33°12′40″
	E. Longitude	75° 74′ 55″ to 79° 04′ 20″
Height (above mean sea level)	m	350 to 6975
Population (Census-2011)	Persons	6856,509

3.1. History and current status of small hydropower in Himachal Pradesh

Evolution of SHPs in Himachal Pradesh dates back to now more than 100 year old. King of erstwhile Chamba princely state (Bhuri Singh Bahadur) was pioneer to start hydropower generation in Himachal Pradesh. He developed the first hydropower project of the state (capacity 0.45 MW) in 1908 [45,46]. Later, more SHPs were installed in Jubbal (1911) and Chhaba (1913) having installed capacities of 50 kW and 1.75 MW, respectively [31,47].

Himachal Pradesh is one of the 'power states' of India with an estimated hydropower potential of 23,000 MW [48]. Status of hydropower potential in Himachal Pradesh has been shown in Table 5. Besides large hydropower projects, this state also has a wide potential of developing SHPs. Total estimated small hydropower potential in Himachal Pradesh from five perennial river basins is about 2400 MW. Out of this potential, only about 537 MW has been harnessed as on 31.12.2012 [37]. Spatial distribution of potential SHP sites in Himachal Pradesh has been shown in Fig. 3. Growth of SHPs (upto 25 MW capacity) in Himachal Pradesh in terms of number of projects implemented and corresponding installed capacity in the past few years has been depicted in Figs. 4 and 5, respectively.

Himurja is the nodal agency in Himachal Pradesh responsible for handling small hydro projects up to 5 MW capacity. This agency has allotted overall 500 SHPs (having cumulative capacity of 1279.43 MW) in state and private sector by end of year 2013. Out of these 500 SHPs, 472 SHPs (having cumulative capacity of 1261.31 MW) have been allotted in private sector since 1995–1996 (when the state government allowed the entry of private sector for exploitation of hydro potential in small hydro sector) [50].

In spite of having good potential, well developed framework and policy for SHP development, the progress in this sector has been sluggish in Himachal Pradesh. Out of 531 potential sites, 511 (more than 95%, having cumulative capacity of about 1300 MW) sites are having installed/potential capacity upto 5 MW. Current status of number of SHPs (up to 5 MW capacity) under various stages of development in Himachal Pradesh has been shown in Fig. 6.

It is clear from Fig. 6 that the growth of SHPs (in major capacity range of upto 5 MW) has not been encouraging in the state in terms of installed capacity and number of projects. Only 79 SHPs (16% projects having cumulative capacity of about 242 MW) have been implemented till date. 51 SHPs (10% projects having cumulative capacity of about 183 MW) are under construction, 124 SHPs (24% projects having cumulative capacity of about 365 MW) are under the process of obtaining clearances and 257 SHPs (50% projects having cumulated capacity of 510 MW) are under investigation stage. It means average implementation rate of SHPs in the state during the last 17 years had been only about 5 projects per year (or only about 14 MW per year in terms of installed capacity). Such a slow rate of SHPs is a matter of concern for SHP planners of the state.

3.2. Himachal Pradesh state government policy for small hydropower development

Government of Himachal Pradesh has adopted a multi pronged strategy for power development through state sector, central sector, joint venture and Independent Power Producers (IIPs). Involvement of private sector agencies in SHPs is a benchmark for small hydropower development in India [31]. State government has taken several initiatives to encourage and attract private sector participation in small hydropower development. Private sector entrepreneurs are also finding attractive business opportunities in SHPs [30]. The state is amongst the few states, which has streamlined and is continuously refining the various procedures/

Table 5
Status of hydropower potential in Himachal Pradesh.
Source: [38].

Sector		Commissioned		Under construction		Obtaining clearances		Under investigation		Others (dispute/cancelled)		Foregone		Grand total	
		No. of projects	Capacity in MW	No. of projects	Capacity in MW	No. of projects	Capacity in MW	No. of projects	Capacity in MW	No. of projects	Capacity in MW	No. of projects	Capacity in MW	No. of projects	Capacity in MW
Himurja	State	10	2.37	0	0.00	15	61.55	1	1.50	0	0.00	0	0.00	26	65.42
	Private	58	219.25	51	182.60	109	303.87	256	508.29	0	0.00	0	0.00	474	1214.01
HPSEBL*	Upto 5 MW	11	21.10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	11	21.10
	> 5 MW	11	456.45	2	110.00	0	0.00	4	70.50	1	6.00	0	0.00	18	642.95
HPPCL#	–	0	0.00	5	856.00	8	1285.00	7	963.00	0	0.00	1	20.00	21	3124.00
Central and joint	–	9	5743.73	4	2532.00	1	66.00	1	588.00	0	0.00	0	0.00	15	8929.73
Yamuna projects (Himachal share)	–	–	131.57	–	–	–	–	–	–	–	–	–	–	–	131.57
Ranjeet Sagar dam (Himachal share)	–	–	27.60	–	–	–	–	–	–	–	–	–	–	–	27.60
Private	–	13	1829.40	24	765.50	24	865.50	30	3354.50	4	986.50	6	735.00	101	8536.40
Total		112	8431.47	86	4446.10	157	2581.92	299	5485.79	5	992.50	7	755.00	666	22,692.78
Balance potential under investigation															307.22
Grand total															23,000.00

* Himachal Pradesh State Electricity Board Ltd.; # Himachal Pradesh Power Corporation Ltd.

processes to minimize the bottlenecks. In order to give a boost to hydropower generation, Himachal Pradesh has formulated Hydropower Policy in year 2006 Hydro projects have been classified into two categories and there are different policy provisions for these two categories. Some of the main provisions with respect to these two categories have been given below [51–53].

3.2.1. Policy guidelines for projects up to 5 MW

1. Projects up to 5 MW capacity have been exclusively reserved for bonafide Himachalis (native state citizens).
2. The government of Himachal Pradesh will get royalty in shape of free power from the small hydro electric projects @ 6% for first 12 years, 15% for the next 18 years and 24% for the remaining period of project agreement. In addition 1% free power will also be provided by the project developer towards Local Area Development Fund (LADF) over and above the normal royalty. The revenue thus generated will be used for socio-economic welfare schemes, developing community facilities and additional basic infrastructure in the project affected areas on a sustained basis throughout the life period of the project. This fund would be available in the form of free power as an annuity over the entire life of the project. Comprehensive guidelines have been issued for the management of the LADF.
3. 1% of the total project cost shall be earmarked for Local Area Development activities and shall be utilized on developmental activities in the project affected areas.
4. Project developers have to hand over the project to the state government after a period of 40 years (reckoned after 30 months from the date of signing of Implementation Agreement).
5. The project developers can also make third party sale or make captive use outside the state for which they have to enter into suitable agreement for transmission of Power with the concerned entities.
6. The company shall have to provide employment to bonafide Himachalis, in respect of all the unskilled/skilled staff and other non-executives as may be required for execution, operation and maintenance of the project. If it is not possible to recruit 100% staff from Himachalis for justifiable reasons, only then the company shall maintain not less than 70% of the total employees/officers/executives from bonafide Himachali persons.
7. The developer of ROR hydropower project shall ensure minimum flow of 15% water immediately downstream of the diversion structure of the project all the times as per the policy of department of environment, government of Himachal Pradesh, as applicable from time to time. The developer shall provide necessary arrangement/mechanism in the civil structure including discharge measurement system for the release of laid down minimum flow immediately downstream of the diversion structure.

3.2.2. Policy guidelines for projects above 5 MW

1. All projects above 5 MW shall be allotted to IPPs (Independent Power Producers) through competitive bidding.
2. The bidders would be required to accept to pay a fixed upfront premium charges of 2000,000/- (Rs. twenty lacs) per MW capacity of the project and 'additional free power' at a uniform rate in all three time-bands of royalty charges during the operation period of the project to the government of Himachal Pradesh over and above the royalty charges of $(12+1)\%$, $(18+1)\%$ and $(30+1)\%$ of the deliverable energy up to 12 years, next 18 years and balance 10 years of the agreement period from

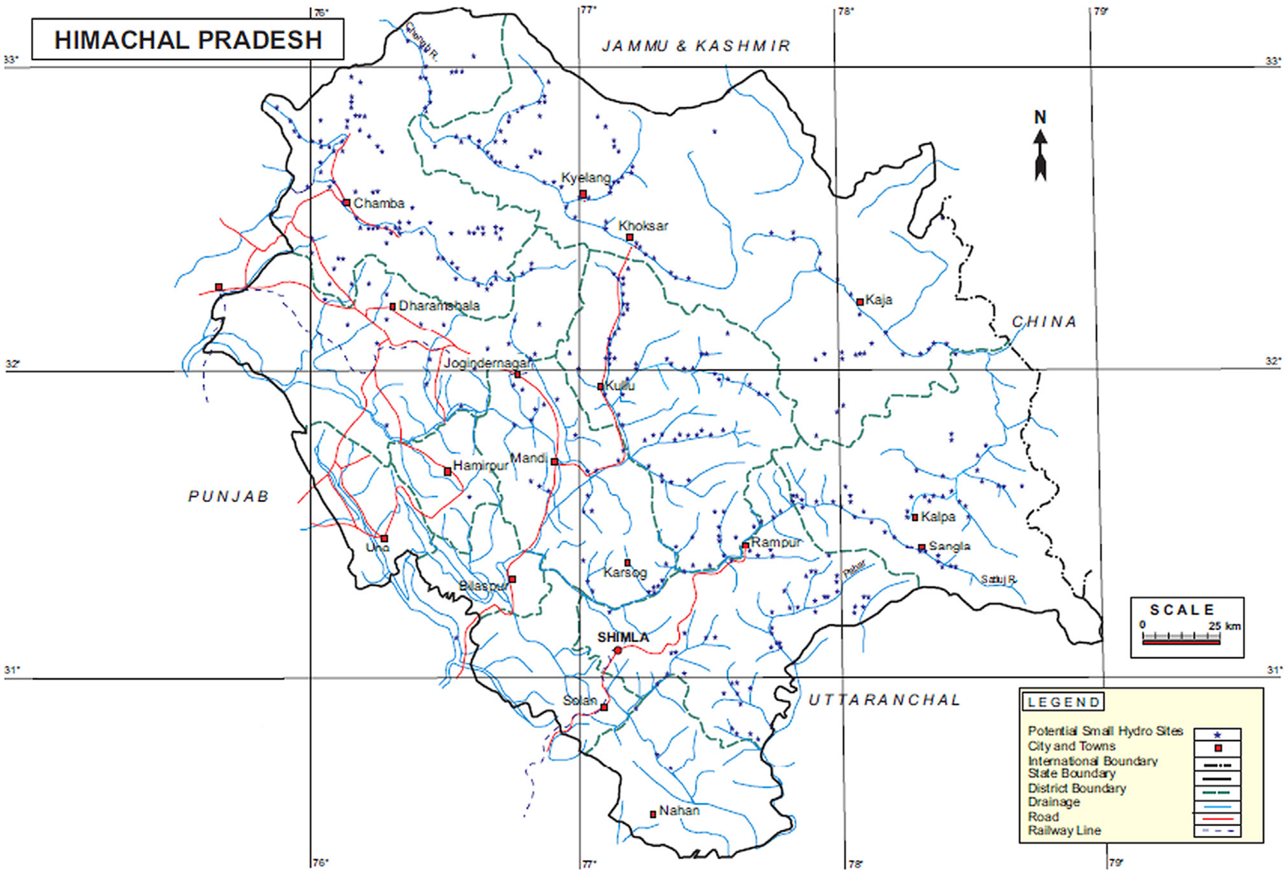

Fig. 3. Spatial distribution of potential SHP sites in Himachal Pradesh [49].

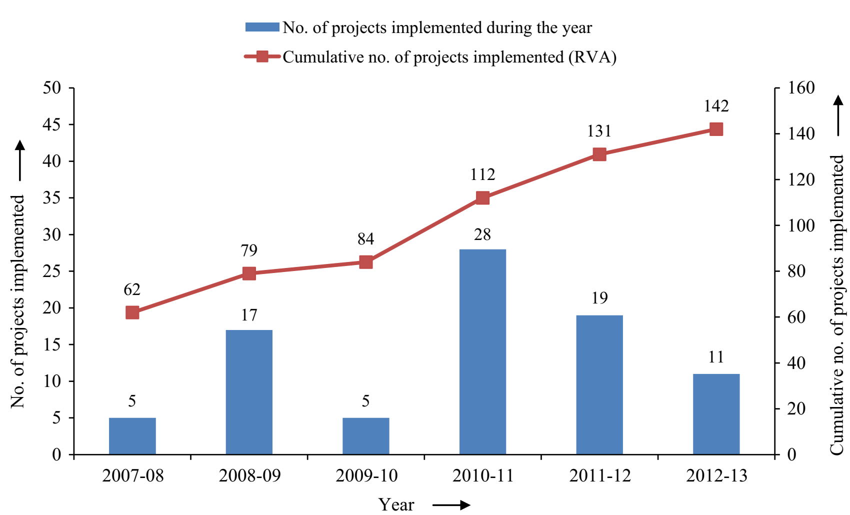

Fig. 4. Growth of number of SHPs in Himachal Pradesh in recent years [37].

scheduled commercial operation date. Additional 1% indicated in these three slabs is the same additional free power as explained at point number 2 in case of project category upto 5 MW.

3. The developer shall make a provision of 1.5% of final cost of the project towards Local Area Development Committee (LADC), the activities of which shall be financed by the project itself.
4. The operation period of the projects shall be 40 years from the schedule commercial operation date (COD) of the projects, where after, the project shall revert to the state government free of cost.
5. The developer shall be free to dispose of such power as remains after meeting commitments of royalty in shape of free power and additional free power through merchant sale.
6. Policy provisions as mentioned under points 5, 6 and 7 for projects upto 5 MW capacity apply same for this category of projects.

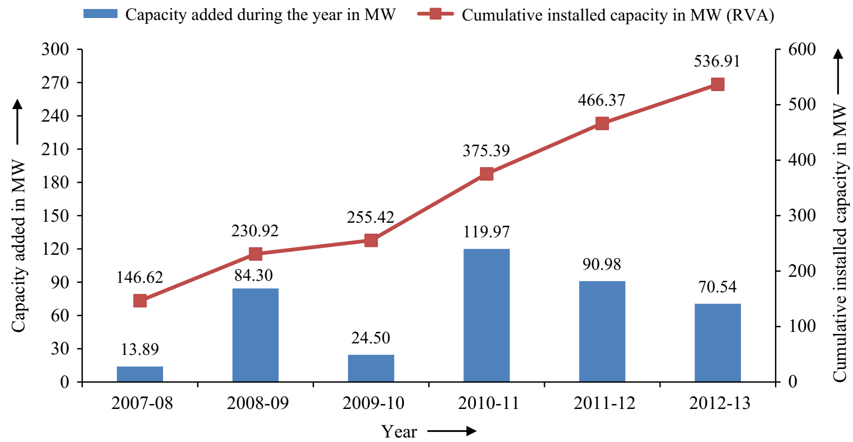

Fig. 5. Growth of installed capacity of SHPs in Himachal Pradesh in recent years [37].

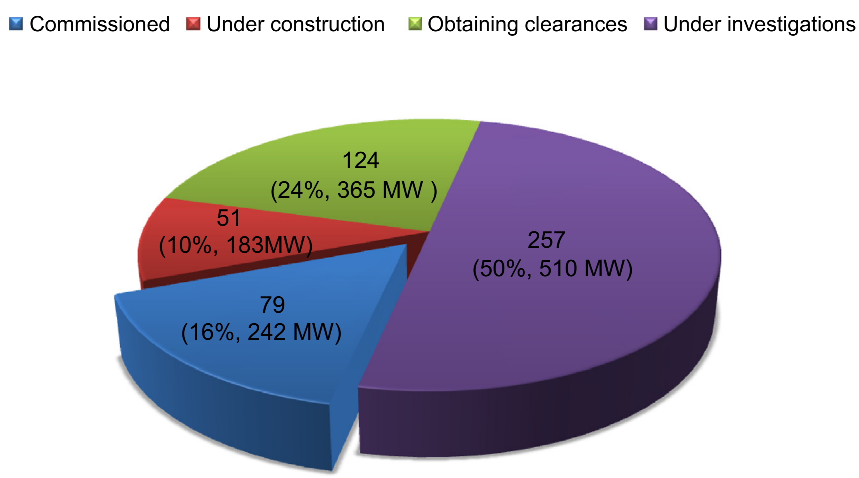

Fig. 6. Current status of number of SHPs (upto 5 MW installed capacity) in Himachal Pradesh [48,50].

3.3. Government of India subsidy scheme for SHPs in Himachal Pradesh

Government of India (through MNRE) is providing capital subsidy through financial institutions like IREDA (Indian Renewable Energy Development Agency Ltd.). The subsidy is intended for making repayment of the term loan provided to the developer of the SHPs by the financial institution. In case of private, co-operative, joint sector etc., the subsidy is released in two instalments (out of which 1st instalment is optional) while in case of the government/state/public sector etc., the subsidy is released in four instalments [54]. The capital subsidy is released to financial institution (s) providing loan to set up SHPs. The quantum of subsidy will be independent of quantum of term loan and will be limited to the amount indicated in Table 6.

Financial support is also provided to Government sector for renovation and modernization of existing SHPs and for carrying out Detailed Survey and Investigation (DSI) and preparation of Detailed Project Report (DPR) of SHPs as indicated in Table 6. Comparatively more financial support has been extended to hydro rich Himalayan states. These states are termed as 'special category states' as per MNRE. Location of these states has been indicated in Fig. 2. Consultancy services in the field of SHPs are available from a number of government/private consultancy organizations. The Ministry is strengthening technical institutions to provide such services. AHEC is providing full range of technical services in the field of small hydro including survey and investigation, DPR preparation, project design etc. On site testing facility has been created at AHEC to test SHP stations for their performance. A Real Time Digital Simulator has been set up at AHEC which is providing hands on experience to operators of SHP stations [55]. In addition to IREDA, other institutions like World Bank, Asian Development Bank, Japan Bank for International Co-operation etc. also finance SHPs.

3.4. Challenges for small hydropower development in Himachal Pradesh

The pressure and challenge before the hydro rich states like Himachal Pradesh is not just to make power, but make 'clean' and 'green' power [56]. There are many types of challenges being faced for smooth and speedy development of SHPs in Himachal Pradesh. These challenges have been highlighted with possible mitigating measures in Table 7.

3.5. Important initiatives taken by the state government

In order to streamline and accelerate the development of hydropower projects in the state, government of Himachal Pradesh has taken some important initiatives as given in Table 8.

Initiatives listed in Table 8 seem to be quite favorable for sustainable development of SHPs in the state. But, some of the

initiatives may not be implemented in letter and spirit without capacity building. For example, a very important aspect of inspection, quality control and monitoring is almost impossible to implement effectively without recruitment, training and mobilization of adequate staff and creation of modern infrastructure (with facility of movement) to handle these aspects.

3.6. Future scope of small hydropower development in India and Himachal Pradesh

A major percentage of small hydropower still remains untapped in India. MNRE has plans to increase the total installed capacity of SHPs to 7000 MW by 2021. Taking into consideration the allotment of sites made by the states, project implementation schedules and with a reasonable growth rate in the sector, MNRE plans to add about 1310 MW capacity during remaining period of 12th Plan (2013–2017). Table 9 gives the year-wise targets for grid interactive SHPs for the period 2013–2017 [70]. Definitely, state of Himachal Pradesh will have to play a big role in achieving these targets as the state is having about 12% of total small hydro potential of the whole country. Himachal Pradesh government envisages 205 MW (5 MW in state sector and 200 MW in private sector) capacity addition under small hydro power during 12th Plan [71].

In the matter of grid integration, the recent amendments in Grid Code are a positive for SHPs. As per new amendments, renewable energy power plants including SHPs with installed capacity of less than 10 MW will be treated as 'must run' under merit order dispatch which means that the utilities should buy the power the SHPs generate even if lower cost electricity is available from other sources [72].

National Action Plan for Climate Change (NAPCC) of Govt. of India (2008) has set the minimum share of renewable energy (RE) in the overall energy procurement of utilities at 10% by 2015 and 15% by 2020. Thus, even if small hydro projects were to maintain its current 13% share of the total RE capacity, the additional demand in the medium term would be significant [14].

4. Discussion

In the regions which are still deprived of electricity/grid isolated, results of small hydropower technology are quite imminent and visible. In contrast to these regions, impacts of SHPs in an already grid connected mountainous region like Himachal Pradesh are difficult to access. Benefits to people in the small hydropower project regions in this state can be said to be marginal. They are limited to employment generation (that too normally during construction phase only), stability of electricity supply and in some areas, ease of communication due to construction of access road by the developer for SHP. Individual benefits to people are meager but at community level, local area development schemes (funded from these projects) are proving to be main positive point in their favor.

As the social welfare part (on account of provision of electricity) is almost already in place, focus and motive of investors and government is more or less only profit making and revenue generation. In this game, local communities and serene environment of the state seem to be losing now. This fact can be experienced by field visits and interacting with project affected communities in the state. In spite of so called effective policies and initiatives taken by the successive governments in Himachal Pradesh, ground realities have not changed, rather deteriorating.

Many small streams, which are lifelines for agriculture and horticulture based economy of Himachal Pradesh are now proposed to be flooded with SHPs one above the other (in cascade fashion). Sustainability of fragile and rich bio-diversity of this region largely depends upon these water lines. Existence of traditional water mills, local kulhs (small irrigational channels) and cremation sites are now under threat. Mandatory environmental flow is rarely released particularly during lean season. People have to pray or request the project authorities to release water for their irrigation/drinking needs and even to facilitate proper cremation.

Easy dumping of muck on forest slopes or along stream course is being done with impunity by developers. Many projects are reported to have encroached upon government and forest land. Inspection and monitoring part to take care of quality control and safety is very weak. Hence, developers become complacent, giving a go-bye to norms. In this scenario, green and clean image of SHPs has become doubtful.

Overall, it can be said that capacity of the nature to feed and sustain un-planned and non-sustainable SHPs may be over in the near future. Environmental and social impacts of poorly planned run of the river SHPs are now not worth ignoring. In fact, their

Table 6
MNRE incentive schemes to promote SHPs in India. *Source*: [54].

S. nos.	Name of the scheme	Applicable area			
		Himachal Pradesh, North Eastern Region, Jammu & Kashmir and Uttarakhand (Special Category States)		Other states	
		Upto 1 MW	Above 1 MW and upto 25 MW	Upto 1 MW	Above 1 MW and upto 25 MW
1	Scheme for finance support to private, co-operative, joint sector etc. to set up new SHPs upto 25 MW capacity	Rs. 20,000/- per kW	Rs. 2.00 crore for 1st MW+Rs. 30 lacs for each additional MW	Rs. 12,000/- per kW	Rs. 1.20 crore for 1st MW+Rs. 20 lacs for each additional MW
2	Scheme for finance support to Government/State/Public sector to set up new SHPs upto 25 MW capacity	Rs. 50,000/- per kW	Rs. 5.00 crore for 1st MW+Rs. 50 lacs for each additional MW	Rs. 25,000/- per kW	Rs. 2.50 crore for 1st MW+Rs. 40 lacs for each additional MW
3	Scheme for finance support to Government sector for renovation and modernisation of existing SHPs upto 25 MW capacity	Rs. 25,000/- per kW	Rs. 2.50 crore for 1st MW+Rs. 50 lacs for each additional MW	Rs. 15,000/- per kW	Rs. 1.50 crore for 1st MW+Rs. 35 lacs for each additional MW
4[a]	Financial support to state government departments/agencies for preparation of DPRs. including detail survey and investigation (DSI) of SHPs upto 25 MW capacity	Max. Rs. 2.00 lacs or actual incurred cost whichever is less	Max. Rs. 5.00 lacs or actual incurred cost whichever is less	Max. Rs. 2.00 lacs or actual incurred cost whichever is less	Max. Rs. 5.00 lacs or actual incurred cost whichever is less

Conversions: 1 US dollar = Rs. 59/- (average as on May 2014), 1 crore = 10 million, 1 lac = 0.10 million.

[a] Incentives under scheme at S. no. 4 are same for all states.

Table 7
Challenges for small hydropower development in Himachal Pradesh and suggestions to mitigation these challenges.

Type of Challenge	Brief description of challenge	Suggestions for mitigation
Economic challenges	• High manpower, material, machinery and transportation cost (due to inhospitable terrain and lack of infrastructural facilities) • Difficulty in arrangement of finance from banks (as development of hydropower is considered a risky affair) • Enhanced rate of compensation due to implementation of new Land Acquisition Act 2013 [57] with effect from 1st January, 2014	• Developer should employ local labor, use locally available construction material. If found suitable, he should try to use maximum quantity of muck generated during construction as aggregates, protection works, filling etc. • Government should liberally allow installation of temporary ropeways to reduce transportation cost and avoiding construction of access roads • Government should revise and update tariff rates time to time in line with increased price index and compensation regime. It may reduce/ waive off entry tax and other taxes for encouraging entry of private investors in this sector • Government may instruct financial institutions to provide soft and easy loans to investors. Further, it may give guarantee (to financers) of some percentage of loan on behalf of investor • The developer should try to get his completed project registered under CDM to attract some carbon based incentives and the government may facilitate him in this matter
Environmental challenges	• Continuous monitoring of mandatory 15% environmental flow for sustainability of aquatic life, water demand for water mills, irrigation and drinking on downstream of intake site • Control of air and noise pollution emanating from construction of access roads, drilling & blasting, dumping of muck etc. • Depletion/diversion of natural water sources • Soil erosion	• Mandatory installation of 'real time online continuous flow measurement and data logging device' should be strictly enforced to ensure 15% environmental flow. Periodic calibration and actual working of this device should also be ensured • Provision, proper design and actual working of fish passage should be strictly enforced in case of applicable streams • Taking only very necessary controlled blasts, sprinkling of water particularly on earthen roads and dumping of muck in designated dumping sites along with protection measures, provision of adequate sound insulation measures in power houses will help in mitigating air and noise pollution • Encouraging the use of portable crushers to facilitate conversion of muck into aggregates at the site itself is also a useful environment control measure • While planning the project components existence of natural water resources should be mapped and every effort should be made to protect these precious gifts of nature • Compensatory afforestation should be carried out in a planned and effective way to control soil erosion
Social challenges	• Conflicts of affected communities with developer on various social issues (mainly employment, fair compensation, granting benefits to only influential sections of society) • Damage to property (houses/fields/orchards) due to project operations such as blasting, movement of heavy construction equipments, dust emission etc. • Interference with local Dev Sthals (places of Gods), natural water sources used for drinking, irrigation etc. • Fulfilment of promises made by the developer.	• Communities should be consulted and their genuine demands and suggestions should be taken care of by the developer • Amount of compensation should be decided in a transparent manner, weaker sections should be given preference in employment • The developer should not make false and unviable promises. Failure to keep these promises will not only damage the image of present developer but also block the entry of prospective project developers in the area • Blasting hours should be fixed in consultation with neighboring communities and fair compensation should be paid in case of extra damage to property. • Government should ensure equitable distribution of LAD (Local Area Development) fund amongst project affected communities • If possible, investor should do some additional social activities like grant of scholarship to poor students, free electricity during community functions, free medical camps, capacity building of youth etc. to win goodwill of project affected communities
Topographical challenges	• Providing of access roads is highly labor intensive and almost economically unviable due to rugged terrain in many regions which are suitable for SHP development • Extension of transmission lines to remote areas for grid connectivity is also very costly affair	• Planning of SHPs should be done in such a way so that multiple developers may share the cost of developing common infrastructure in a specific hydro attractive region. Government should also bear some percentage of this cost as development of access road will also benefit native people in these areas • Most of identified SHPs are still in under investigation stage in Himachal Pradesh. Hence, still it is time to undertake their development in a planned way
Geological challenges	• Being located in young fragile Himalayan zone, almost all hydropower projects face geological risks and surprises such as unstable strata, 'caving in' of tunnels, frequent landslides, subsidence of land etc. • Geological surprises are main cause of time and cost over-runs in case of hydropower development	• Many times developers ignore/pay less attention to avoid the money to be paid for geological investigations and taking services of a geologist before commencement of work. This may prove to be suicidal in many cases. Hence proper geological investigation at the project site and services of a qualified geologist are must • Use of modern surveying and geological techniques (involving lasers, sensors etc.) may be especially helpful. These techniques may be costly to use but, their use may avoid crucial time and cost over-runs at later stage

Table 7 (*continued*)

Type of Challenge	Brief description of challenge	Suggestions for mitigation
Hydrological challenges	• Lack of correct /long time hydrological data at the project site may cause under-estimation or over-estimation of discharge • Being planned on glacier fed streams and ROR type (with no/ negligible provision of storage); it is very difficult to maintain economic efficiency of SHPs owing to great variation in stream discharge during summer/monsoon and winter season	• A reliable hydrological data base of every hydro rich catchment and accurate system of weather forecasting should be developed • Even if such system is already in place, there is need to update and revise it after a fixed period of time (say once in every 10 years) for long term sustainability of SHPs. This has particularly become essential in view of reported phenomenon of climate change in many river basins in Himachal Pradesh
Technological challenges	• Improving the quality of planning & investigation, reducing construction delays • Improving the life and performance of turbines • Minimizing problems in transportation of bulky and heavy equipment to remote project sites and to cope up with space constrains in power houses • Shortening of diversion reach (but not affecting the generation) to minimize environmental impacts on downstream • Remote monitoring of SHPs	• Use of advance techniques for planning & investigations of SHPs like GIS, digital terrain mapping • Use of advance construction materials, supplements, admixtures which can gain strength early even in harsh cold climate • Designing and using the turbines with metallurgical improvement (so that they are affected least even in case of large sediments in stream thus avoiding frequent shut-downs in monsoon season) and more flexibility to cater to large scale variation in discharge in case of glacial fed streams • Use of split transformers, gas insulated substations will be helpful to cope up with space constrains in power houses • Design, development and use of low head technologies will result in reducing diverted stretches, short head race tunnels and availability of more riparian distance between two projects (in case of cascade development of SHPs) • Use of IT, remote sensing and sensor technology is helpful in remote monitoring of SHPs
Administrative challenges	• Long delays (2 to 3 years) in granting multiple NOCs (from different departments, village level institutions), techno-economic clearance, land acquisition, forest clearance, signing of MOU, IA (Implementation Agreement), PPA (Power Purchase Agreement) etc.	• Process should be made streamlined, simplified and time bound at different levels • Instead of multiple NOCs from different department, single NOC should be granted by calling a meeting of all officials of different departments, community representatives at one place (single window system). Any query or objections raised should be sorted out by higher officials with in a time frame
Quality control, safety and monitoring challenges	• Difficulties in carrying out periodic quality control and safety checks during execution and monitoring of projects after commissioning owing to remoteness of sites and shortage of trained staff in controlling agency	• Recruitment of new staff, hands-on training to new and existing staff to carry out quality control and safety checks at project sites. The staff should be equipped with modern, easy to use, quick result indicating and handy equipments to carry out quality control checks. Further, facilities for quick mobilization should be liberally provided to carry out surprise inspections in project areas • In case of SHPs built on BOOT (build, own, operate and transfer) basis, monitoring after commissioning is also very important to ensure handing over project in sound condition to government after stipulated period of 40 years
Climate change challenges	• Coping up with alarming glacial retreat in this Himalayan prefecture as already predicted and proved by many studies [58–61] • Problems due to frequent flash floods, landslides, increased sediment flow • Likely reduction in rainfall and snow in the medium to long term	• Effect of climate change should be considered in the design of upcoming projects to avoid their abandoning risk in future. However, to include this aspect, region specific reliable studies will need to be carried out • Disaster mitigation and preparedness plan is desired to be prepared to minimize the damage due to natural calamities • Future prospects of installation of hybrid systems (wind-small hydro, solar-small hydro) should be studied to mitigate impacts due to reduction in precipitation
Policy challenges	• Acceptance of policy provisions to both developers and affected communities • Confusion among investors about policy norms	• Hydropower policies should be clear and refined to accommodate genuine and constructive suggestions from developers and project affected communities • To avoid confusion among investors, frequent changes in the hydropower policy should be refrained • Specific and clear guidelines for allotment of projects and leaving minimum riparian distance between two projects should be framed and implemented especially in case of cascade SHPs

adverse effects have already begun to surface out. People are now quite upset over false promises of developers and apathy of officials towards their problems arising out of SHP development in their regions. They have started realizing that due to development of SHPs in their areas, they are going to gain less and loose much more in terms of environmental degradation and deterioration in social values. Voices of opposition are now becoming vociferous. Projects' related conflicts and court cases are on the rise.

In view of the state of affairs mentioned in above paragraphs, healthy inter-relationship and interaction between three main stakeholders of SHPs viz. project developer, government officials (implementing agency) and local project affected community has

become imperative. Without this, smooth and timely completion of SHPs is almost impossible. All policies, initiatives and efforts to promote these projects will fail if this part is not taken care of. It is high time that lagging social and environmental aspects should take the seat along with their economic counterpart for a sustainable development of SHPs in Himachal Pradesh.

The project developer should understand local people's problems; provide them correct information about the project including the advantages and disadvantages of the project. He should organize a group meeting before starting construction in order to know people's opinions and expectations about the project. He should take a lead to fulfill his corporate social responsibilities. He can arrange for additional water supply to the communities, encourage agriculture and fish breeding, promote the project as a tourist attraction, hire a local labor force for the construction and maintenance of the facility, pay fair compensation and return the profits to the community by genuinely contributing to the local area development (LAD) fund. He should plan construction of the project in such a way so that there is minimum disturbance to the ecology, natural resources and livelihood of the local people. He should try to take steps for capacity building of youth and women in the project area.

The government should act as a facilitator and mediator between the project developer and local people. It should act as a watchdog. Committees (including community leaders, government officials and representatives from the project developer) can be formed to monitor the project and solve disputes related to project(s) time to time. Steps should be taken to recover the natural resources and ecology if spoiled by construction activities. Government can reduce/waive off electricity charges for the local

Table 8
Important initiatives taken by Himachal Pradesh for development of small hydropower.

Type of initiative	Brief description of the initiative	Expected outcome of the initiative taken
Economic	• 5% entry tax on hydro project machineries has been abolished and 2% Value Added Tax (VAT) on machineries has been cut [53] • Lease money (on the basis of existing circle rate of land) has been reduced to 3% from the existing 10% for SHPs up to 5 MW capacity • HPERC (Himachal Pradesh Electricity Regulatory Commission) has announced special generic levelized tariff regime especially for SHPs (as compared to large hydropower projects) [62] • Projects up to 2 MW capacity have been exempted from paying any compensation to fisheries department (earlier charged on per MW basis for sustaining aquatic life). Free power for this category of projects has also been reduced from 7% to 3% (for the first 12 years) [63]	• It will help in attracting private investors for development of SHPs in the state
Environmental	• Basin wise impact assessment studies have been initiated with the help of national agencies of repute [52] • A unique project to maintain People's Biodiversity Register (PBRs) at *Gram Panchayat* (an elected village level body in India), level to document as well as safe guard bio-resources and associated knowledge has been initiated [64]. Regular updating of this register will help in estimating the effect of climate change or any man made activity (including construction of hydropower projects) on bio-diversity of the region • Installation of "real time continuous flow measurement and data logging device" has been made mandatory for all the existing and upcoming hydropower projects. [65] • Norms for installation of captive stone crushers and ropeways have been relaxed [63]	• It will help in mitigating environmental impacts due to hydropower projects
Social	• Elaborate guidelines/parameters have been defined for allocation of LAD (Local Area Development) funds starting from project affected area to *Gram Panchayat*, block and district level [66] • The investor shall provide an additional 1% free power from the hydropower projects. Revenue received from such 1% power has been earmarked for Local Area Development Fund (LADF) aimed at providing regular stream of income over the life of the project for development of project affected community • Policy has been framed to pay compensation to project affected people for damage to crops due to construction of hydropower projects [67]	• It will help in generating goodwill and acceptance of communities towards SHPs
Technological	• Digitization of basin wise plans, identification of new projects and optimization has been carried out [52]	• It will result into optimization of total hydro potential of the state
Administrative	• Small hydropower producers have been exempted to take NOC from Irrigation & Public Health, Public Works, Revenue and Fisheries departments [63] • A single Joint Inspection Committee is proposed to be constituted to clear all aspects of projects for statutory clearances [63]	• It will cut down on long delays for grant of statutory clearances
Quality control and monitoring	• A programming has been formulated to monitor detailed progress of milestones through online monitoring of all ongoing project activities, allowing access to the developer for their respective projects [52] • A quality assurance and quality control manual has been prepared to ensure quality and safety of power projects under construction and under operation. To monitor the quality aspects on regular basis, a quality control cell and a quality audit team has been created [68]	• It will help in timely implementation of SHPs • It will ensure quality construction, long life and less operation & maintenance costs of hydropower projects
Forum of hydropower producers	• A forum of hydropower producers (with respect to five river basins of the state) has been constituted to join efforts to pursue eco-friendly hydropower development, comprehensive planning & operations of hydropower projects, sharing facilities/data and forward constructive suggestions to government for modification/improvement of hydropower sector [69]	• It will help in optimisation of resources, data, infrastructure etc. for hydropower development

Table 9
Year-wise targets for grid interactive small hydropower capacity in India for the period 2013–2017.
Source: [70].

Year	Capacity (MW)
Up to 31.12.2013	3763.15 (cumulative capacity actually attained)
2013–2014	300
2014–2015	300
2015–2016	350
2016–2017	360
Total target for the 4-year period	1310

villagers at least for domestic use. It should ensure that compensation and employment is distributed fairly among the project affected communities. It should also facilitate the developer by speedy clearances, providing access roads and granting them various incentives.

The local communities should allow project development in their area. They should co-operate with the project developers and government officials. They should not un-necessarily harass the developer and refrain from extracting exorbitant compensation. Village representatives should be included in committees formed to monitor safety and security aspects as well as environmental protection during the project construction and operation. Local NGOs can also play an important role in guiding and educating the local communities about pros and cons of the SHPs in their area.

Last but not the least, government at central and state level should now seriously give a thought to include SHPs (2 to 25 MW) under the process of environmental clearance. Of course, the strategy and norms may not be equivalent to that for a large hydropower project. Imbibing this process in small hydropower development may not be conducive to government and investors for the time being but, in the long run this will help to win crucial goodwill of project affected communities and enhance the 'mother' nature's capacity to support these ventures. Many hydro rich countries like Turkey, Brazil and Serbia had already taken a stride in this direction and taken SHPs under the ambit of EIA [26,28,73].

5. Conclusion

Small hydro projects are hydro dollar minting machines for mountainous states like Himachal Pradesh. Although Himachal Pradesh has taken a lead by framing good policies and guidelines for smooth development of SHPs yet pace of tapping small hydro potential is not up to mark. Sustainability is the buzz word these days and without sustainable policies, these small projects will act as slow poison for the livelihood of native people. Hence, Himachal Pradesh government and policy makers should endeavor to take steps to involve and take into confidence the native people while setting norms and guidelines for developing small projects in their areas.

Some element of environmental clearance (though not of the level of large hydropower projects) is now required to be incorporated in the sector of small hydropower development in order to prevent unplanned and haphazard development of these projects. To start with, SHPs above 5 MW capacity may be taken into the ambit of environmental clearance. Framing of policies favoring sustainable development and their effective implementation at grass-root level (involving all stakeholders) can only set the ball rolling for desired pace of small hydropower development in the state. It is hoped that the excerpts from this study may be helpful in other similar regions of the South Asia in particular and the world in general for development of small hydropower projects.

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